IS 9716 (1981): Guide for lateral dynamic load test on piles [CED 43: Soil and Foundation Engineering]

BLANK PAGE

Indian Standard
GUIDE FOR LATERAL DYNAMIC LOAD TEST ON PILES

(First Reprint OCTOBER 1997)

UDC 624.154 : 624.042.8 : 006.76

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *June* 1981

Indian Standard

GUIDE FOR LATERAL DYNAMIC LOAD TEST ON PILES

Foundation Engineering Sectional Committee, BDC 43

Chairman	*Representing*
PROF DINESH MOHAN	Central Building Research Institute (CSIR), Roorkee
Members	
DR R. K. BHANDARI	Central Building Research Institute (CSIR), Roorkee
CHIEF ENGINEER	Calcutta Port Trust, Calcutta
SHRI S. GUHA (*Alternate*)	
SHRI M. G. DANDAVATE	The Concrete Association of India, Bombay
SHRI N. C. DUGGAL (*Alternate*)	
DR R. K. DAS GUPTA	Simplex Concrete Piles (India) Pvt Ltd, Calcutta
ADDITIONAL CHIEF ENGINEER (*Alternate*)	
SHRI A. G. DASTIDAR	In personal capacity (*5 Hungerford Road, 121 Hungerford Street, Calcutta*)
SHRI V. C. DESHPANDE	The Pressure Piling Co (I) Pvt Ltd, Bombay
DIRECTOR (CSMRS)	Central Water & Power Commission, New Delhi
DEPUTY DIRECTOR (CSMRS) (*Alternate*)	
SHRI A. H. DIVANJI	Asia Foundations and Construction Co Pvt Ltd, Bombay
SHRI A. N. JANGLE (*Alternate*)	
DR JAGDISH NARAIN	Indian Geotechnic Society, New Delhi
PROF SWAMI SARAN (*Alternate*)	
SHRI G. S. JAIN	G. S. Jain & Associates, Roorkee
SHRI ASHOK KUMAR JAIN (*Alternate*)	
JOINT DIRECTOR (D)	National Buildings Organisation, New Delhi
SHRI SUNIL BERY (*Alternate*)	
JOINT DIRECTOR RESEARCH (SM)	Ministry of Railways (RDSO)
JOINT DIRECTOR RESEARCH (B & S) (*Alternate*)	
DR R. K. KATTI	Indian Institute of Technology, Bombay
SHRI S. R. KULKARNI	M. N. Dastur & Co Pvt Ltd, Calcutta
SHRI S. ROY (*Alternate*)	
SHRI O. P. MALHOTRA	Public Works Department, Chandigarh Administration, Chandigarh
SHRI A. P. MATHUR	Central Warehousing Corporation, New Delhi
SHRI V. B. MATHUR	Machenzies Limited, Bombay
SHRI T. K. D. MUNSI	Engineers India Limited, New Delhi
SHRI M. IYENGAR (*Alternate*)	

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
BRIG OMBIR SINGH	Engineer-in-Chief's Branch, Army Headquarters, New Delhi
MAJ H. K. BHUTANI (*Alternate*)	
SHRI B. K. PANTHAKY	The Hindustan Construction Company Limited, Bombay
SHRI V. M. MADGE (*Alternate*)	
SHRI M. R. PUNJA	Cemindia Co Ltd, Bombay
SHRI S. MUKHERJEE (*Alternate*)	
SHRI N. E. V. RAGHVAN	The Braithwaite Burn & Jessop Construction Co Ltd, Calcutta
SHRI A. A. RAJU	Vijayanagar Steel Plant (Steal Authority of India), New Delhi
PROF GOPAL RANJAN	University of Roorkee, Roorkee
SHRI T. N. SUBBA RAO	Gammon India Limited, Bombay
SHRI S. A. REDDI (*Alternate*)	
SHRI Y. V. NARASIMHA RAO	Bokaro Steel Plant (Steel Authority of India), Bokaro
DR V. V. S. RAO	Nagadi Consultants Pvt Ltd, New Delhi
SHRI ARJUN RIJHSINGHANI	Cement Corporation of India, New Delhi
SHRI O. S. SRIVASTAVA (*Alternate*)	
DR A. SARGUNAN	College of Engineering, Guindy
SHRI S. BOOMINATHAN (*Alternate*)	
SHRI K. R. SAXENA	Public Works Department, Government of Andhra Pradesh, Hyderabad
DR S. P. SHRIVASTAVA	United Technical Consultants Pvt Ltd, New Delhi
DR R. KAPUR (*Alternate*)	
SHRI N. SIVAGURU	Ministry of Shipping and Transport, New Delhi
SHRI D. V. SIKKA (*Alternate*)	
SUPERINTENDING ENGINEER (DESIGNS)	Central Public Works Department, New Delhi
EXECUTIVE ENGINEER (DESIGNS) V (*Alternate*)	
SHRI M. D. TAMBEKAR	Bombay Port Trust, Bombay
DR A. VARADARAJAN	Indian Institute of Technology, New Delhi
DR R. KANIRAJ (*Alternate*)	
SHRI G. RAMAN, Director (Civ Engg)	Director General, BIS (*Ex-officio Member*)

Secretary

SHRI K. M. MATHUR
Deputy Director (Civ Engg), BIS

Pile Foundations Subcommittee, BDC 43 : 5

Convener	
SHRI M. D. TAMBEKAR	Bombay Port Trust, Bombay
Members	
DEPUTY DIRECTOR RESEARCH (SM II), RDSO	Ministry of Railways, Lucknow
DEPUTY DIRECTOR STANDARDS (B & S/CB II), RDSO (*Alternate*)	

(*Continued on page* 19)

Indian Standard

GUIDE FOR LATERAL DYNAMIC LOAD TEST ON PILES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 January 1981, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The pile foundation is one of the common type of foundations used under favourable soil conditions for various structures subjected to dynamic loads resulting from seismic activity, waves, etc. Design of pile foundations subjected to dynamic loads specially in earthquake zones requires the determination of response of soil-pile system under horizontal dynamic loads for different modes of vibrations. The method of analysis requires the use of natural frequencies of soil-pile system under different modes of vibrations, damping coefficient and also overall soil-pile stiffness coefficients under dynamic loads. The *in situ* test on piles subjected to lateral vibrations is the most reliable method to obtain the said data. The standard has been prepared to provide the guidelines for carrying out such tests.

0.2.1 The response of pile subjected to dynamic loads depends upon the subsoil, the restraints offered by the superstructure of pile top, the sustained load carried by the pile and the nature of ground motion. Since the piles are usually installed in groups, overall behaviour of pile foundation depends upon group behaviour.

0.3 Formulation of this standard is the first attempt in this direction and the provisions made are mainly based on the tests carried out by the Roorkee University, Roorkee.

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding of numerical values (*revised*).

1. SCOPE

1.1 This standard lays down the method of conducting lateral dynamic load tests under both free and forced vibrations on all type of piles which develop resistance from bending or friction or both by the contact with soil and interpretation of data.

2. TERMINOLOGY

2.0 For the purpose of this standard, the relevant definitions given in IS : 2810-1979*, IS : 2911 (Part I/Sec 1 to 3)-1979†, IS : 2911 (Part II)-1980†, IS : 2911 (Part III)-1980†, IS : 2911 (Part IV)-1979†, IS : 5249-1977‡ and the following shall apply.

2.1 Eccentricity, θ — Angle between eccentric masses of the oscillator. Also defined in terms of distance in unit of length.

2.2 Dynamic Force, F_0 — Force imparted during vibrations which is function of eccentric mass in the oscillator, eccentricity level and forcing frequency level.

2.3 Coefficient of Subgrade Reaction (Modulus of Subgrade Reaction of Soil Modulus, k **) (** FL^{-3} **)** — Ratio of load per unit area to horizontal surface of a mass of soil to corresponding settlement. Thus the coefficient of horizontal subgrade reaction (modulus of horizontal subgrade reaction or horizontal soil modulus), k_x is the ratio of horizontal load per unit area of vertical surface of a mass of soil to corresponding horizontal deflection, that is, $k_x = p/y$, where p is horizontal load per unit area (soil reaction) and y is horizontal deflection. It is considered constant with depth for preconsolidated clays and increasing with depth or granular soils and normally consolidated clays.

NOTE — For a pile of width or diameter, B in the relation $k_x = p/y$, p is given as force per unit length of pile divided by width or diameter B. In case of clays k'_x is taken constant with depth and for granular soils $k'_x = n_h . x$, where n_h (FL^{-3}) is coefficient of proportionality for defining increase in horizontal soil modulus with depth, x. The soil stiffness is expressed in terms of soil modulus and for dynamic loading condition be determined using lateral dynamic load test data.

2.4 Soil-Pile Stiffness (Overall Stiffness of Soil-Pile System), k_{hp} **(** FL^{-1} **)** — Dynamic force per unit deflection where deflection is taken equal to static amplitude (δst) worked out from dynamic load tests data and dynamic force as in **6.7**.

---

*Glossary of terms relating to soil dynamics (*first revision*).

†Code of practice for design and construction of pile foundations:

Part I Concrete piles, Section 1 Driven cast-in-situ concrete piles; Section 2 Bored cast-in-situ concrete piles; Section 3 Driven precast concrete piles (*first revision*).
Part II Timber piles (*first revision*).
Part III Under-reamed piles (*first revision*).
Part IV Load test on piles.

‡Method of test for determination of dynamic properties of soils (*first revision*).

3. NECESSARY INFORMATION

3.1 The following information is necessary for the pile on which the test is to be conducted:

a) *Pile Type* — Material and reinforcement details, method of installation including data of driving or casting or both.

b) Pile depth, cut off level and details of cross section.

c) Piling plan and location of pile in the group including if it is a test pile or working pile. Also the condition of pile to be used in actual case, that is, under a cap resting on ground due to scour or otherwise.

d) Sub-soil strata details including position of water table.

e) Allowable and ultimate vertical load carrying capacity. In case of working pile, actual design loads both in vertical and lateral direction coming on the pile including static moments.

f) Type of structure under which piles are being used, nature of loading, for example, seismic loads.

g) Any other relevant information concerning with planning and conducting the tests including the past experience on similar tests.

4. EQUIPMENT

4.1 The equipment normally used for the tests are similar to those given in IS : 5249-1977*. Main features of the equipment are given in the following clauses.

4.1.1 *Mechanical Oscillator* — The mechanical oscillator should be capable of producing a sinusoidally varying force and have a frequency range commensurate with the pile type, its geometry and type of soil. It should have the provision for altering dynamic force level by simple adjustment of eccentric masses.

4.1.2 *DC Motor* —Motor of suitable power rating so as to run the above mechanical oscillator in the required frequency range at full load. This should be of type that its own vibrations are negligible.

4.1.3 *Speed Control Unit* — Capacity commensurate with dc motor being used, capable of operation at 220 V ac input supply and giving variable dc voltage output. The maximum drop in voltage at full load should not exceed 2 percent.

4.1.4 *Acceleration Pick-Up* — Three in number, of same response characteristics, maximum range should commensurate with equipment

*Method of test for determination of dynamic properties of soils (*first revision*).

used in **4.1**, useful frequency range dc 100 Hz or more. Natural frequency should be 220 Hz undamped and 140 Hz damped. The response should be linear, deviation from linearity being 1 percent or less with amplitude changes.

4.1.5 *Displacement Pick-Up* — Amplitude may be directly measured using displacement pick-ups. These should be of appropriate capacity and should have flat frequency response in the range 0 to 100 Hz or more and should be of high sensitivity; accuracy should be not less than 2 percent.

4.1.6 *Universal Amplifier* — Frequency response dc 100 Hz high sensitivity with oscillograph which should not be less than 1V per chart line, maximum voltage gain should 1 500 000; bridge exciter frequency should 2 000 Hz ± 5 percent.

4.1.7 *Ink Writing Oscillograph* — Frequency response above 100 Hz; number of elements 3 (perferable); natural frequency above 140 Hz; maximum amplitude ± 20 mm; paper speed 5, 25, 125 mm/second; capable of operation at 220 V ac 50 Hz supply, optimum damping with external resistance.

4.1.8 *Cathode Ray Oscilloscope* — Of sensitivity 1 mV/cm to at least 125 V/cm; accuracy : ± 5 percent, stability : 1 mV/h after warm up; band width; dc coupling: 0 to 300 Hz, ac coupling: 2 Hz to 300 K Hz; power supply: 115/230 V ± 10 percent, frequency: 50/100 Hz.

4.1.9 *Phase Meter* — Frequency range 5 to 100 Hz, phase difference 0 to 180° with a minimum accuracy of 1 percent at the centre and 3 percent at the ends. The input signal range may be 1 mV to 5 V.

4.1.10 *Steel Plate for Fixing Oscillator and dc Motor* — Thickness 25 mm, length and width depending upon size of oscillator unit.

4.1.11 *Attachments for Free Vibration Test* — A suitable device to apply the necessary pull in horizontal direction on pile and attachment to release it suddenly. One such device could be suitably designed pulling screw to produce different pulling forces in horizontal direction. The releasing of load could be done with the help of a clutch type arrangement. The releasing clutch and pulling screw be connected to a clamp attached to the pile.

5. TEST ON PILES

5.1 General

5.1.1 Two type of tests, namely, free and forced vibration lateral tests shall be carried out to observe response of soil-pile system under horizontal dynamic loads and for the evaluation of soil-pile stiffness, soil modulus, natural frequency, time period and damping characteristics of the soil-pile system.

5.1.2 The number of tests depend on site conditions and pile types used at a particular site. However, there shall be a minimum of three representative piles of same type in almost similar soil conditions at a particular site. Two piles out of three piles be preferably at one place so that one could be used to provide reaction for other during the application of horizontal load in free vibration tests.

5.1.2.1 Free vibration tests shall be conducted first on two adjacent piles and then forced vibration on these piles. The third pile shall only be tested under forced vibrations.

5.1.3 The tests could be carried out on test piles and/or working piles. The tests shall preferably be conducted on a pile after a month on its installation particularly in case of cohesive deposits. However, the tests may be conducted earlier if it is required from design or performance considerations. In case of cast-in-situ concrete piles, the test shall be conducted after 28 days to enable pile to develop the structural strength unless rapid hardening cement has been used.

5.1.4 *Preparation of Pile Head* — Depending upon the pile material, type and conditions of the test, top of pile will need suitable preparation for carrying out the tests. For lateral forced vibration test, the pile should project beyond cut off level to a minimum distance of 75 cm for fixing attachments to mount plate with clamps supporting oscillator motor assembly. The pile top shall be levelled smooth. If required for fixing plates, etc, a suitable cap may be cast on the pile top. The cap be kept resting on ground or free standing as the case may be. In order to fix the clamp properly on the pile for free vibration test, surface of the extended portion of pile should be smoothened as far as possible.

5.1.5 The tests normally be carried out without sustained vertical load other than that of the oscillator assembly. However, in case the imparting dynamic force by the oscillator is not sufficient to create almost resonance condition, the sustained weight can be used to increase dynamic force to obtain resonance or nearly resonance condition.

5.2 Free Vibration Tests

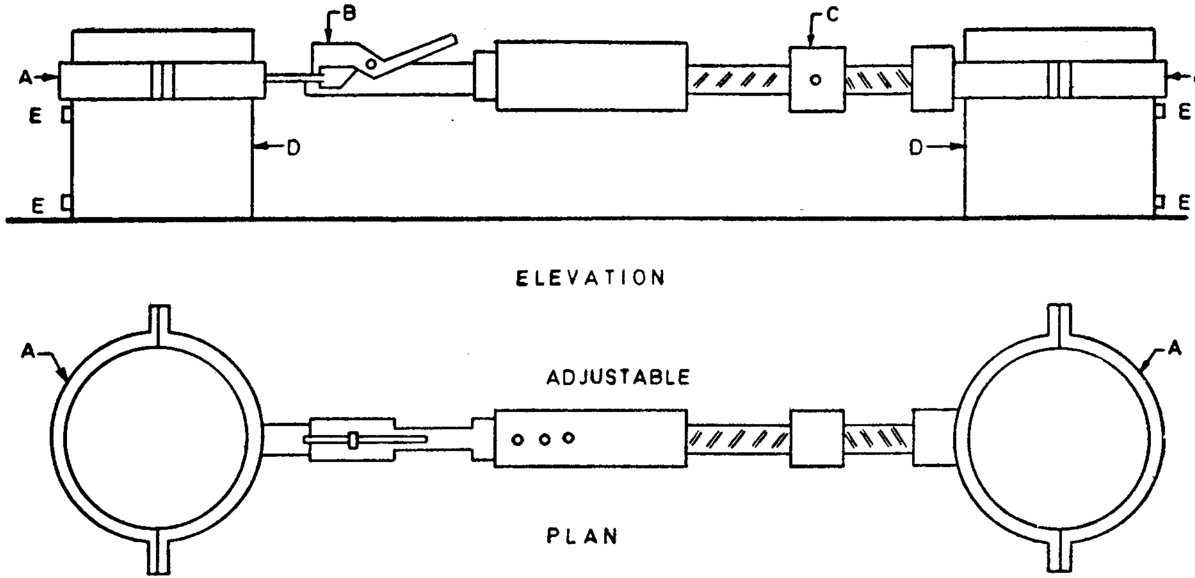
5.2.1 *Test Set-Up* — The set-up for free vibration tests esssentially consists of the arrangements for applying horizontal load on pile and its sudden release. One such type of set up is shown in Fig. 1. The horizontal load on pile is applied by rotating the pulling screw duly calibrated and then suddenly releasing the load with the help of clutch type attachment. The clamps on pile be fixed tightly. For sensing the vibrations two acceleration pick-ups (inductance type) duly calibrated as in **5.2.2** shall be used. The pick-ups be mounted in the plane of vibrations. One pick-up shall be mounted close to the top of pile or at pile cap and the other to pile near ground level or cut off level. The pick-ups be securely attached to the concrete sections using chemical resins. For recording, the displacement pick-ups may also be used which will provide the direct measurement of amplitude. To record time history of acceleration measurements (varying signal response), the pick-ups are connected with amplifier and ink writing oscillograph. The motor be attached to a speed control unit to control the speed to motor. Suitable connections between power supply, speed control unit, amplifier and ink writing oscillograph are made as shown in Fig. 2.

5.2.2 *Calibration of Acceleration Pick-Up* — Each acceleration pick-up shall be calibrated before conducting the test and also at the end of each test to find out any possible changes in calibration during test. For calibration of acceleration pick-up, after making electrical connections, hold the pick-up with its axis vertical and turn gradually through 90° in a vertical plane, hold for a while when the displacement of the pen in writing oscillograph is maximum from its mean position, then turn the pick-up through another 90°. The whole process may be repeated two or three times to obtain average calibration of pick-up. The peak to peak displacement represents an acceleration of 2 g at the corresponding chart multiplier.

5.2.3 *Test Procedure* — Initially choosing an appropriate value of horizontal load, the load shall be applied by rotating pulling screw and it shall be suddenly released through the clutch attachment. The pile soil system which has been displaced from equilibrium position under application of the load, when released oscillates under its natural frequency of vibrations. The signals of the pick-up amplified through amplifier are recorded by direct writing oscillograph. Several tests shall be conducted applying different horizontal loads and observations be taken corresponding to each load level. For test piles in case of earthquake loading the maximum horizontal load shall be limited such that it causes a maximum deflection of about 10 to 12 mm and for working piles this limit load be restricted to a corresponding maximum deflection of about 4 to 5 mm. Typical free vibration test records using acceleration pick-ups are shown in Fig. 3.

5.3 Forced Vibration Tests

5.3.1 *Test Set-Up* — The mechanical oscillator and dc motor shall be fixed rigidly on the plate mounted on pile top (*see* Fig. 4) such that the oscillator assembly is along the vertical axis of pile and it generates horizontal sinusoidal vibrations. One such type of arrangement for fixing oscillator-motor assembly on plate mounted on pile top using fabricated attachments is shown in Fig. 4. The fixing attachments along with frame and bolts shall properly be designed to support oscillator motor assembly during testing without any distortion, etc.



A — Clamp around pile
B — Releasing clutch
C — Pulling screw
D — Piles under test
E — Acceleration pick-ups

FIG. 1 SET-UP FOR FREE VIBRATION TEST

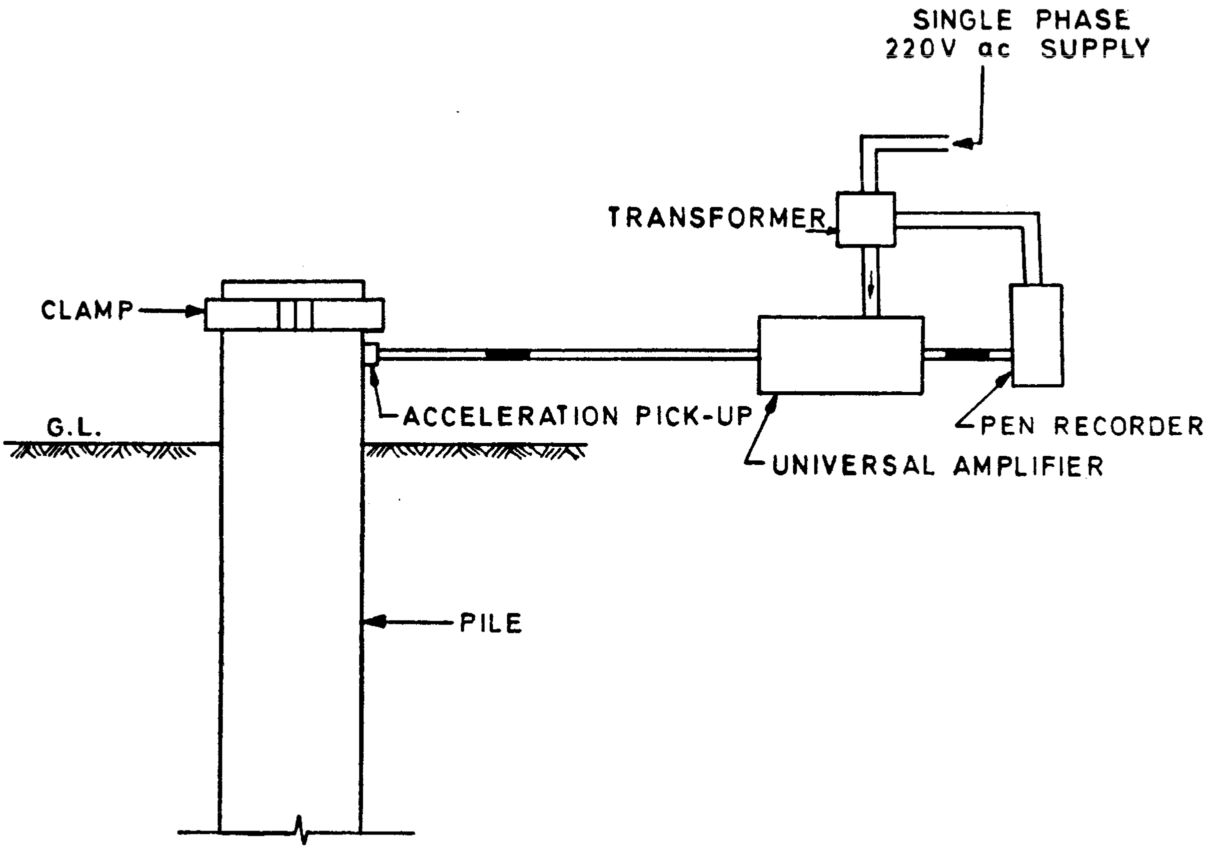


FIG. 2 BLOCK DIAGRAM OF TESTING EQUIPMENT FOR FREE VIBRATION TEST

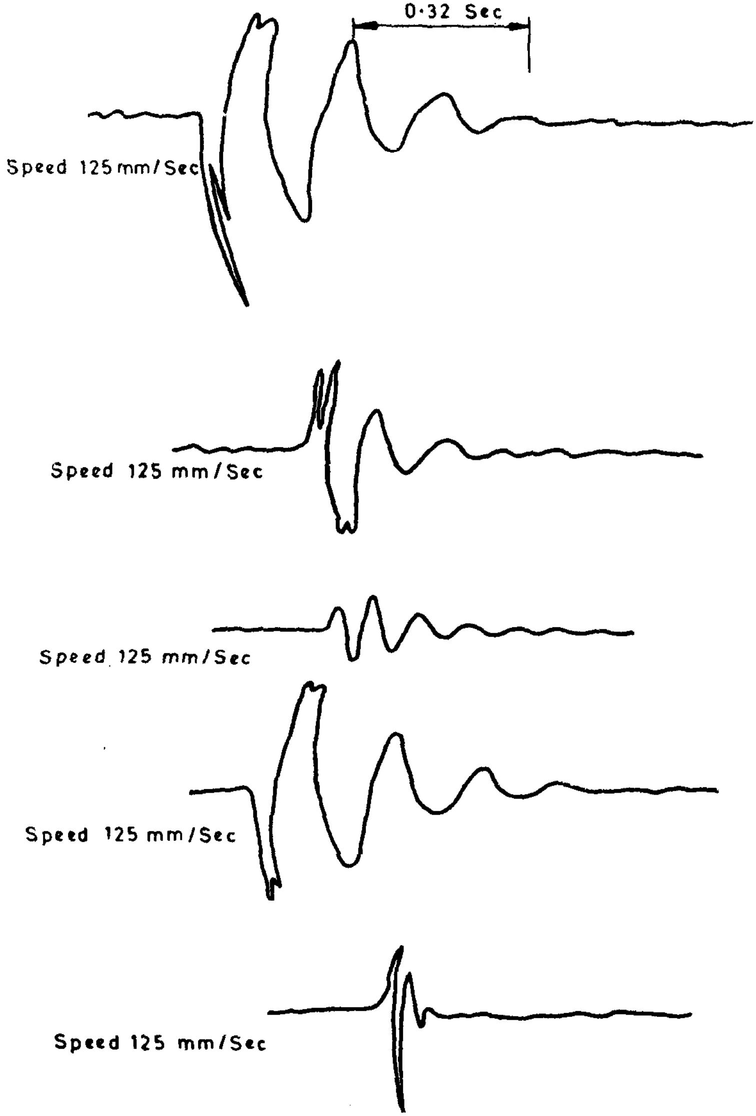


FIG. 3 TYPICAL FREE VIBRATION TEST RECORDS ON A PILE

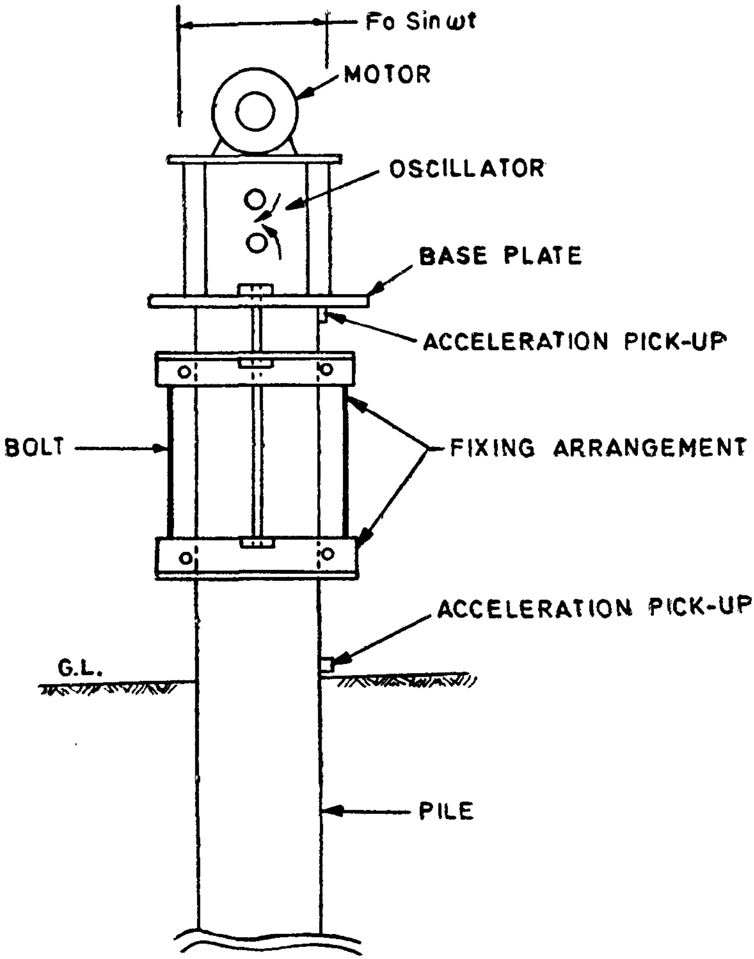


Fig. 4 Lateral Forced Vibration Test Set-Up

5.3.2 *Test Procedure* — The oscillator is driven with the help of dc motor using pulleys and belt drives. Two equal eccentric masses attached in the oscillator rotates at the same angular frequency of motor but in opposite directions to each other, thereby producing a sinusoidal force perpendicular to the plane passing through the two axes of rotation.

After choosing a suitable value of angle of setting of eccentric masses (say 8°), the oscillator shall be made to run at a constant frequency. The signals of the pick-ups which are amplified through amplifier are recorded by the direct writing oscillograph. The frequency of the oscillator shall be increased in steps and the signals be recorded corresponding to each frequency level. The records shall be taken corresponding to about 20 different frequency levels allowing sufficient time for the system to reach steady state at each frequency level. For increasing frequency of oscillator, the speed of motor is changed with the help of speed control unit. The records similar to above shall be taken corresponding to different eccentricity levels, increasing eccentricity in steps of about 8°. Variations in eccentricity levels and frequency levels shall be done such that corresponding to resonance or almost resonance, these covers vibrations of amplitude of twice the permissible value in case of test pile and equal to permissible value for working pile. As a rough guide for earthquake loading, the maximum limit of amplitude may be taken about 10 to 12 mm in case of test pile and about 5 mm in case of working pile. Typical acceleration time records obtained using acceleration pick-ups for sensing the vibrations are shown in Fig. 5.

6. ANALYSIS OF TEST DATA

6.1 Frequency of Vibrations — From the records, knowing paper speed in oscillograph, the frequency shall be worked out using following equation:

$$f = \frac{n \times s}{l} \qquad \text{......(1)}$$

where

f = frequency in Hz;

n = number of cycles in the length of record, l in mm; and

s = paper speed in mm/sec.

The angular frequency, w (radian/sec²) shall be given by $w = 2\pi f$ and the time period in second is given as inverse of the frequency in cps.

6.2 Amplitude of Vibrations — From the observed values of frequency and acceleration, the amplitude of horizontal vibrations, A_x (mm) shall be obtained from the relationship:

$$A_x = \frac{a_x}{4\pi^2 f^2} \qquad \text{......(2)}$$

where

a_x = horizontal acceleration of vibration in mm/sec² at frequency, f in Hz.

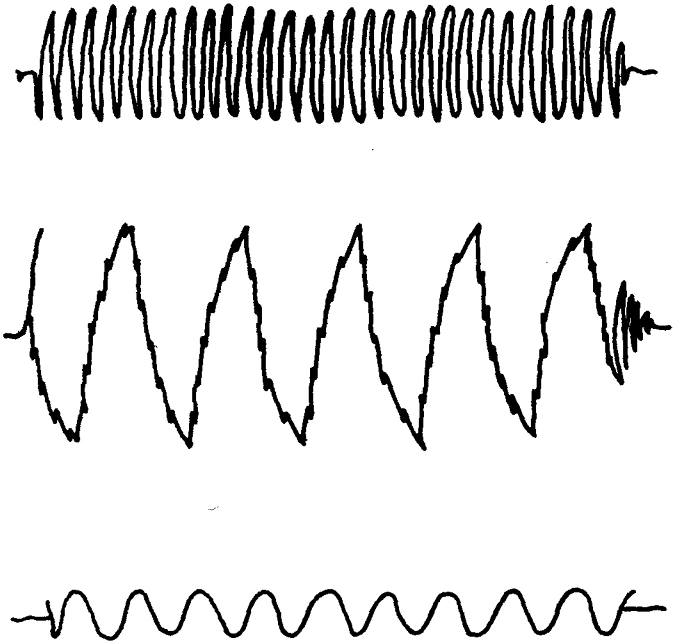


Fig. 5 Typical Acceleration Time Records for Lateral Dynamic Load Test on a Pile Under Forced Vibrations

6.3 Imparted Dynamic Force — In forced vibration tests, the imparted dynamic force, F_0 (kg) corresponding to a particular eccentricity level and frequency shall be calculated using the following equation:

$$F_0 = m\, e\, w^2 \qquad \ldots\ldots(3)$$

where

m = eccentric mass in kg sec^2/mm;

e = eccentricity in mm; and

w = forcing frequency obtained from forced vibration records as described in **6.1**.

Note — One of the suggested tabular form for the record of above quantities (*see* **6.1** to **6.3**) for forced vibration test is given in Appendix A.

6.4 Natural Frequency — From the free vibration test records, the natural frequency, f_n shall be worked out as given in **6.1**. The natural frequency shall be obtained corresponding to different load levels (different displacements from equilibrium position) for each pile and a weighted average of these values be taken for the use. The natural frequency should be choosen from the later part of record.

6.5 Damping Coefficient — Damping coefficient, ξ shall be obtained from free vibration records using the following equation:

$$\xi = \frac{1}{2\pi} \log_e \left(\frac{A_m}{A_m + 1} \right) \qquad \text{..... (4)}$$

where

A_m and $A_m + 1$ are the maximum amplitude of vibrations in two successive cycles.

The damping coefficient shall be calculated from different free vibration tests and a weighted average be taken for use.

6.6 Soil-Pile Response Under Forced Vibration Tests

6.6.1 The amplitude vs frequency data obtained in **6.1** and **6.2** from forced vibration records be plotted corresponding to different eccentricity levels. The resonant frequency given by the frequency corresponding to maximum amplitude shall be determined for each eccentricity level. It will be different at different eccentricity levels due to the fact that the effect of different eccentricities is to cause different strain levels.

6.6.2 For different frequency levels, the dynamic force as obtained in **6.3** from forced vibration test records shall be plotted against amplitude.

6.7 Soil-Pile Stiffness, k_{hp}

6.7.1 Using the plots made in **6.6.1** and **6.6.2** and considering variation of resonant frequencies at each eccentricity level, the static amplitude, δ_{st} (mm) corresponding to different dynamic force (F_0) and forcing frequency (w_n) shall be worked out from the following relationship:

$$\delta_{st} = \frac{A_x}{\mu} \qquad \text{......(5)}$$

where

A_x = dynamic amplitude of vibration in mm; and

μ = magnification ratio, given by:

$$= \frac{1}{\sqrt{\left[\left\{1-\left(\frac{w}{w_n}\right)^2\right\}^2+\left(2\xi\frac{w}{w_n}\right)^2\right]}} \quad ......(6)$$

in which

ξ = damping coefficient as calculated in **6.5**,

w = forcing frequency, and

w_n = resonant frequency.

NOTE — To simulate earthquake loading condition in which the amplitudes are usually large, static amplitude (δ_{st}) are normally worked out corresponding to the frequencies which are nearer to the resonant frequencies, that is, close to maximum amplitudes.

6.7.2 A plot shall be made between the dynamic force (F_o) and static amplitude (δst). The tangent modulus of this plot gives the soil-pile stiffness (k_{hp}) under dynamic loading condition.

NOTE — The above interpretation is based on the assumption that for all practical purposes there is a unique variation in δ_{st} with F_0 irrespective of variation in forcing (w) and resonant frequency (w_n) as these are taken corresponding to larger amplitudes.

6.8 Soil Modulus

6.8.1 In case of granular soils and soils in which the soil modulus is taken as increasing with depth, coefficient of horizontal soil modulus variation or horizontal soil stiffness variation (n_h) shall be obtained using relationship:

$$n_h = \frac{EI}{T^5} \quad ......(7)$$

where

E = modulus of elasticity of pile material in kgf/cm^2,

I = moment of inertia of pile section in cm^4, and

T = relative stiffness factor in cm

calculated by the equation:

$$T = \left(\frac{EI}{A_y} \cdot \frac{1}{k_{hp}} \right)^{\frac{1}{5}} \qquad \ldots\ldots(8)$$

where

k_{hp} = soil-pile stiffness in kg/cm as worked out in **6.7**, and

A_y = deflection coefficient equal to 2·435 at ground surface for free headed piles.

6.8.2 For piles embedded in clays in which the soil modulus is taken *constant* with depth, the soil modulus (k'_x) shall be determined from the following equation:

$$k'_x = \frac{EI}{R^4} \qquad \ldots\ldots(9)$$

where

R = relative stiffness factor in cm, obtained from the relationship:

$$R = \left(\frac{EI}{A_z} - \frac{1}{k_{hp}} \right)^{\frac{1}{4}} \qquad \ldots\ldots(10)$$

where

k_{hp} = soil-pile stiffness in kg/cm obtained in **6.7**;

A_z = deflection coefficient equation to 1·40 for free headed pile at ground surface; and

E, I have the same meaning as in **6.8.1**.

7. REPORT

7.1 The report on lateral dynamic load tests shall contain all relevant information concerning the piles and tests. It should include observations in the form of vibration records and tables alongwith the analysis of test data giving the plots for soil-pile response, natural frequency of the soil pile system, dampling coefficient, soil-pile stiffness and soil modulus. The text in the report should be illustrated with appropriate figures.

APPENDIX A

(*Clause* 6.3)

LATERAL FORCED VIBRATION TEST ON PILE

(Using acceleration pick-ups calibrated at chart multiplication factor 100)

SITE........................... PILE DETAILS.........................

Pick-up calibrated length (K) = ... mm for an acceleration of 2 g (2 × 9 810 mm/sec²) at chart multiplication factor 1 000

Paper speed in oscillograph (S) = ...mm/awx

Eccentric mass of oscillator (m) = kg sec²/mm

1 Sl No.	2 Eccentricity (e) mm	3 Chart multiplication factor at the time of test	4 Length of record mm	5 No. of cycles in the length of record (column 4) (n)	6 Frequency (f) Hz $= \frac{n \times s}{\text{Length of record}}$	7 f^2	8 $4\pi^2f^2$	9 Acceleration on record (peak to peak) mm	10 Absolute acceleration col (9) × col (3) $= \frac{x^2 \times 9\,810}{1\,000 \times K}$	11 Amplitude (A_x) $\frac{\text{Column (10)}}{4\pi^2 f^2}$	12 Dynamic force (F_0) kg $m \times e \times 4\pi^2 f^2$	13 Remarks

(*Continued from page* 2)

Members	*Representing*
SHRI M. IYENGAR	Engineers India Limited, New Delhi
SHRI J. K. BAGCHI (*Alternate*)	
SHRI B. K. PANTHAKY	Hindustan Construction Co Ltd, Bombay
SHRI P. V. NAIK (*Alternate*)	
SHRI M. R. PUNJA	Cemindia Co Ltd, Bombay
SHRI S. MUKHERJEE (*Alternate*)	
SHRI D. SHARMA	Central Building Research Institute, Roorkee
SUPERINTENDING ENGINEER (DESIGNS), CENTRAL DESIGNS ORGANISATION	Central Public Works Department, New Delhi
EXECUTIVE ENGINEER (DESIGNS) V (*Alternate*)	

BUREAU OF INDIAN STANDARDS

***Headquarters*:**

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones: 323 0131, 323 3375, 323 9402

Fax : 91 11 3234062, 91 11 3239399, 91 11 3239382

Telegrams : Manaksanstha (Common to all Offices)

	Telephone
***Central Laboratory*:**	
Plot No. 20/9, Site IV, Sahibabad Industrial Area, Sahibabad 201010	8-77 00 32
Regional Offices:	
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	323 76 17
*Eastern : 1/14 CIT Scheme VII M, V.I.P. Road, Maniktola, CALCUTTA 700054	337 86 62
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43
Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113	235 23 15
†Western : Manakalaya, E9, Behind Marol Telephone Exchange, Andheri (East), MUMBAI 400093	832 92 95
Branch Offices::	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMEDABAD 380001	550 13 48
‡Peenya Industrial Area, 1st Stage, Bangalore-Tumkur Road, BANGALORE 560058	839 49 55
Gangotri Complex, 5th Floor, Bhadbhada Road, T.T. Nagar, BHOPAL 462003	55 40 21
Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No.29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
NIT BUilding, Second Floor, Gokulpat Market, NAGPUR 440010	52 51 71
Patliputra Industrial Estate, PATNA 800013	26 23 05
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35
T.C. No. 14/1421, University P. O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17

---

*Sales Office is at 5 Chowringhee Approach, P.O. Princep Street, CALCUTTA 700072	27 10 85
†Sales Office is at Novelty Chambers, Grant Road, MUMBAI 400007	309 65 28
‡Sales Office is at 'F' Block, Unity Building, Narashimaraja Square, BANGALORE 560002	222 39 71

Printed at Printograph, New Delhi (INDIA).